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IN **AEROSPACE**

Recommendations for the HUMS R&D Plan – Smiths Perspectives

FAA HUMS Research Review Meeting

9 December 2004

Smiths Study

- **HUMS manufacturer input to the development of a HUMS R&D plan for near-term (5 year) and long-term (10 year) goals.**
- **Report delivered Nov 2004**
- **Study Considered:**
  - Background and Current State of Health and Usage Monitoring Systems
  - Issues for R&D in FAA Areas of Interest
  - Analysis of Future HUMS Requirements
  - Gap Analysis
  - Recommended FAA Sponsored R&D Projects

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Issues for R&D in FAA Areas of Interest

Issues related to COTS HUM systems

Use of HUMS to support fault-tolerant aircraft design

Improvement of HUMS sensor technologies

Use of HUMS for on-board crew warnings

Issues Related To COTS HUM Systems

- **Obsolescence**
  - Verify that hardware and software can be upgraded without having to re-certify
- **Open Systems Data Integrity**
  - Internet Viewing
  - Viruses and worms
  - Use of third party data viewers
  - Transfer of the data over the internet
- **Flexibility**
  - Incorporation of new reports
  - User configurability

Use Of HUMS To Support Fault-Tolerant Design

- **Two primary areas of opportunity to support damage tolerance:**
  - Quantification of the operational usage of the mechanical components
  - Provision of the ability to detect damage once it has occurred within the component

- **Usage monitoring**
  - Monitor the loads that a given component experiences
  - Provide information on how damaging an environment an individual component has been exposed to

- **Damage detection**
  - HUMS has been proven in an operational environment to detect faults
  - Improvements in sensor technologies required for HUMS to be the sole means of detection

Improvement Of HUMS Sensor Technologies

- **Identify a rationale for the advancement of:**
  - Sensor technologies
  - Signal processing techniques
  - Data mining and analysis technologies
  - Automated reasoning technologies

CAA Study on HUMS Performance

- **This analysis utilizes:**
  - Smiths Aerospace database of HUMS in-service experience
  - Information on accidents and incidents to HUMS
- **Effectiveness of HUMS**
  - Must consider complete chain that ends in the decision being made
  - Chain includes:
    - Appropriate sensors
    - Algorithms that extract component health information
    - Alerting strategies and methodologies that trigger human intervention at the appropriate time
    - Unambiguous diagnostic and prognostic information to guide appropriate maintenance actions
    - Operational policies, procedures and trained personnel

On-board Warning to Flight Crew

- **Provision and use of HUMS to provide on-board warning to flight crew has long been an area of debate:**
  - Logical extension of ground based fault detection
  - Cockpit indication needs to have a sufficiently low false alarm rate and be linked to specific operating instructions
- **UK Air Accident Investigation Branch issued a recommendation that:**
  - “The CAA should develop the concept of providing flight deck display of HUMS exceedance information, including vibration, to flight crew”
- **Helicopter Health Monitoring Advisory Group (HHMAG) set up a working group to review this recommendation**

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On-board Warning to Flight Crew (2)

- **Summary**
  - In order to develop in-flight warning or the use of HUMS as an on-demand information source for the aircrew, the following areas will require further analysis:
    - Better understanding of the distribution of warning reliability by the mechanical component and health indicators
    - Potential for the advanced anomaly detection methodologies to be implemented in an on-board system
    - Methodologies for the presentation of health status information to the aircrew and integration with operational procedures

Analysis of Future HUMS Requirements

Future HUMS Requirements

- **System architecture**
  - On board processing
  - On board storage
  - Avionic integration
- **Sensors / monitoring**
  - Swashplate
  - Continuous monitoring
- **Usage**
  - Expanded structural and transmission usage monitoring
  - Derived parameters
- **FOQA / HOMP**
  - Operational monitoring

Future HUMS Requirements

- **Anomaly Detection**
  - Multivariable anomaly detection
- **Diagnostics**
  - Automated diagnostics
- **Prognostics**
  - Predictive capability
- **Data Management**
  - Integrated download from vehicle
  - Centralized data management
  - Support for deployed operations
- **Infrastructure**
  - Integration with maintenance manuals and procedures

Gap Analysis

Gap Analysis

- **Validation of Certification procedures**
  - Functionality of one component may be partitioned and certified to different levels
  - Use of automated testing to reduce certification costs
  - HUMS software configuration is typically modified throughout the product lifecycle
  - HUMS data is stored in remote databases and viewed through an Internet browser or web-enabled application

- **COTS Issues**
  - Windows OS changes frequently due to service packs and updates
  - Ground based system can be connected to a network or the Internet
  - Wireless data transfer

Gap Analysis

- **Advancement and Demonstration of Sensor Technologies**
  - Rotor system fault detection
  - Improved effectiveness of epicyclic stage monitoring
  - Enhanced anomaly detection
  - Automated diagnostics
  - Prognostics
  - Integration with maintenance practices / policy
  - Oil condition monitoring

- **On Board Warnings**
  - False alarm rate requirements
  - Use of on-demand information by aircrew
  - Use of health status information pre and post flight

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Recommended FAA Sponsored R&D Projects

Automated testing

System partitioning

Automated diagnostic reasoning

Strategy for prognostics

Cockpit indications

Automated Testing

- **Potential to reduce the overall cost and time required for certification**
- **Research the impact of automated testing on the certification process**
- **Plan**
  - Analyze the various forms and tools associated with automated testing
  - Analyze the utilization of automated testing in a project
  - Implement automated testing on a portion of the system
  - Verify the tests capture potential failures
- **Goal**
  - Develop and demonstrate automated testing for HUMS
  - Report to detail the guidelines for the implementation and execution of automated testing
- **Cost**
  - Program is scalable
  - Estimated duration of one to two years

System Partitioning

- **Potential to reduce the overall cost and time required for recertification**
- **Research the partitioning of the HUMS into many sub-certifiable parts to reduce the effort associated with the recertification process**
- **Plan**
  - Analyze and detail all of the systems and subsystems in the HUMS
  - Verify the changes in one partition do not impact the other partitions
  - Provide recommendations to the FAA
- **Goal**
  - Develop and demonstrate the partitioning of the HUMS into certifiable components to reduce the amount of the system that must be tested when a change is incorporated
  - Report suggested modifications or updates to the advisory circular
- **Cost**
  - Program is scalable
  - Estimated duration of one to two years

Automated Diagnostic Reasoning

- **Develop and test an intelligent HUMS data management system that incorporates new anomaly detection and diagnostic techniques**
- **Plan**
  - Develop reasoning technology based on Causal Networks for HUMS.
  - Demonstrate automated reasoning technology on real-world data
  - Provide solutions for some of the difficult knowledge engineering tasks
- **Goal**
  - Develop and demonstrate an automated reasoning system for HUMS
  - Provide improved diagnosis of mechanical faults on the helicopter drive system
  - Outcome will aid the development of HUMS related aircraft maintenance procedures to help improve maintenance effectiveness and reduce operating cost
- **Cost**
  - Two year program

Strategy for Prognostics

- **Extend the significant research that is being performed on model-based prognostics for simple configurations by investigating complex configurations**
- **Plan**
  - Research multi-dimensional strategy for the achievement of a practical prognostic capability
  - Address requirements for the practical application of the strategy
  - Ensure effective supervision of prognostic outputs
- **Goal**
  - Perform research into a practical strategy for the implementation of HUMS prognostics
  - Optimize the planning of future maintenance while ensuring continued airworthiness
  - Demonstrate the strategy using real data for several prognostic scenarios
- **Cost**
  - Two year program

Cockpit Indications

- **Address the validity of providing both warnings and supplementary on-demand health information to aircrews**
- **Plan**
  - Perform a study based on existing operational databases into the distribution of health indicator reliability
  - Investigate the human factors issues associated with the presentation of health information to the aircrew
- **Goal**
  - Research distribution of health indicator reliability by mechanical component
  - Identify a subset of the health monitoring dataset where there is sufficient confidence that the use of the data in the cockpit can be considered.
  - Recommend the appropriate human factors associated with providing health information to the aircrew.
- **Cost**
  - Two year program

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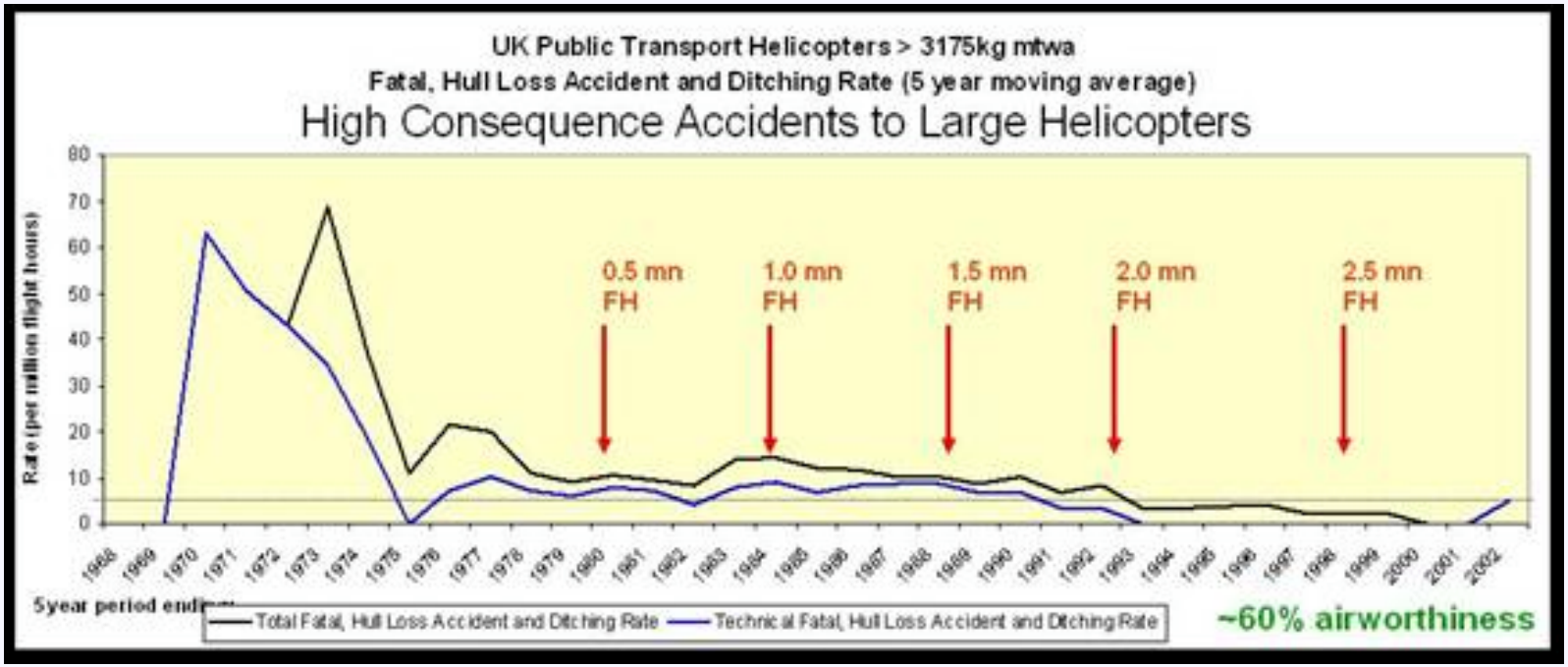
BACKUP SLIDES

Sensor Technologies

- **UK accident statistics**



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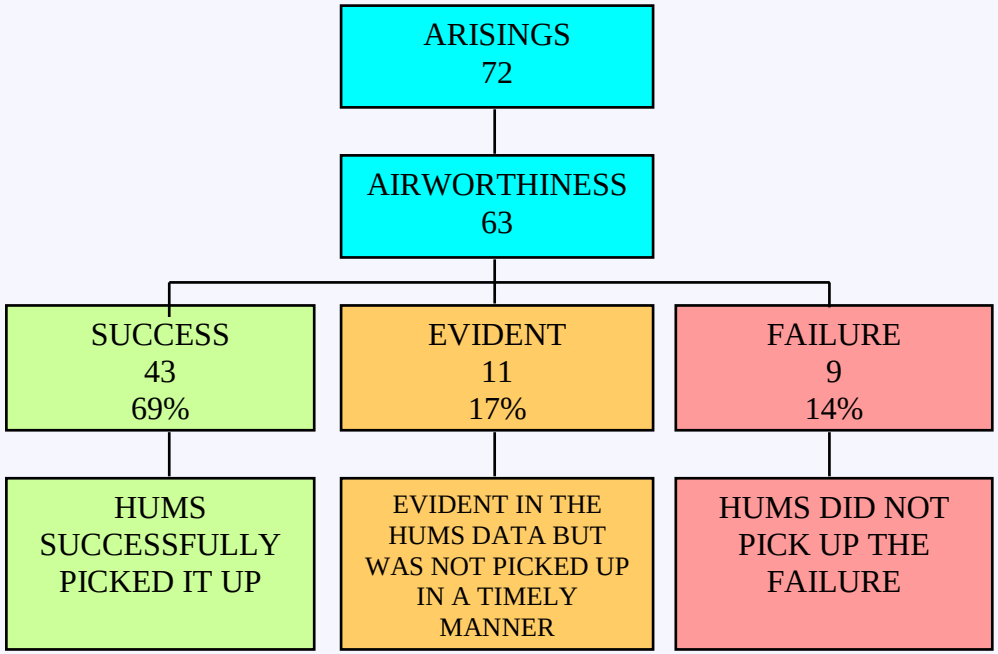
- **CAA study on HUMS performance**



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Sensor Technologies

- **Key incidents and accidents involving HUMS equipped helicopter**
  - AS332L Super Puma – GPUMH 27th September 1995
  - AS332L Super Puma – LNOPG 8th September 1997
  - AS332 Super Puma
  - Sikorsky S76 G-BJVX 16th July 2002
  - Sikorsky S61-N G-BBHM

Sensor Technologies

- **Summary**
  - The weakness of the current generation of HUMS can be divided into two categories:
    - Mechanical components of the helicopter where HUMS has had a lower success rate in detecting faults
    - Process leading to a maintenance or airworthiness decision on the helicopter
  - Mechanical components
    - Rotor system faults
    - Main transmission epicyclic stages
    - Accessory gearboxes
  - Process related
    - Fault isolation
    - Prognostics
    - Self monitoring

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